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By

James Eugene Morris

ATMOSPHERIC SCIENCES LABORATORY
U. S. ARMY ELECTRONICS COMMAND
WHITE SANDS MISSILE RANGE, NEW MEXICO

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ABSTRACT

Mesospheric wind data obtained with a new high altitude Loki system during the summer of 1966 over Fort Greely, Alaska, are presented. Soundings, utilizing very light chaff as a wind sensor, were scheduled near noon and midnight for a 50-hour period. These data are from a sparsely sampled region of the atmosphere. The diurnal variations and the high velocities observed give valuable information regarding noctilucent clouds, atmospheric tidal oscillations, and the mean summer flow near the subpolar mesopause.

CONTENTS

1. Introduction

Rocketsonde wind measurements have steadily increased in number during the last six years. Although more than 6,000 soundings have been made available to the scientific community through Meteorological Rocket Network (MRN) publications,* data are still considered very limited in number, altitude, and geographical extent as pertains to climatological studies. Consequently, new data from a portion of the atmosphere not yet sampled, or sparsely sampled, are of particular interest. A portion of the wind data discussed in this paper was obtained in the 70-80 km region of the atmosphere over Fort Greely, Alaska (64°00' N 145°44' W). Data have been limited in the past to approximately 60-65 km in altitude over Fort Greely and have been sparse above this altitude throughout the MRN. In addition, the data from Fort Greely were obtained in early August and correspond to the season, altitude and latitude where noctilucent clouds are observed.

2. Data Acquisition and Preliminary Analysis

To probe the wind structure in the mesopause region, 15 high-energy Lokis were fired, of which five were test fired at White Sands Missile Range, New Mexico (WSMR), and 10 at Fort Greely. According to the manufacturer, this high-energy motor utilizes the same hardware and grain design as the standard Loki, but the oxidizer content is increased to attain a higher apogee. A slim 1.250 in. diameter dart was used, with 0.001 in. diameter glass chaff in eleven of the darts and 0.0025 in. diameter copper chaff in the remainder.

Of the five performance rounds fired at WSMR in June and July, only one was considered optimum, with failure of radar skin track accounting for most of the less than optimum rounds. The optimum

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*Inter-Range Instrumentation Group, Range Commander's Council, 1964, 1965: Data report of the Meteorological Rocket Network firings. Volumes I-LIV, U. S. Army Electronics Research and Development Activity, White Sands Missile Range, New Mexico. (U. S. Government agencies may obtain copies from the Secretariat, Range Commander's Council, ATTN: STEWS-SA-S-RCC, White Sands Missile Range, New Mexico 88002. U. S. aerospace industries, universities, foreign requests, et al. should be directed to Defense Documentation Center (DDC), ATTN: DDC-IRA, Cameron Station, Alexandria, Virginia 22314.)

round, utilizing 0.001 in. diameter glass chaff, was fired on 8 July 1966 at 1230 LST, and attained an altitude of 89.3 km. Wind data were reduced graphically from the radar plots with the top data point at 86 km and the bottom data point at 66 km. The wind profile from 66 to 41 km was obtained with a second sounding fired at 0745 LST on 8 July 1966, utilizing 0.0025 copper chaff. This profile (Figure 1) shows the jet-like zonal wind near 65 km. The peak in the summer easterlies is normally near the top of MRN rocketsonde data, leaving some doubt as to the average level of maximum easterly flow. Average zonal speed at the 65 km level over WSMR in July, based on 28 soundings made over a 6-year period, is 55 mps as compared to 113 mps on 8 July 1966, indicating that the level of maximum easterly flow is not always reached, or that this 113 mps speed is unusual. The combining of these two soundings leaves no doubt as to the existence of this sharp peak in the easterly circulation near 65 km. It will be noted later in this report that the maximum easterly wind at 65 km over WSMR is considerably lower in altitude than the subpolar maximum in easterly winds.

The remaining 10 high-energy Loki motors and slim dart systems were fired at Fort Greely beginning at noon on 6 August 1966 and continuing through 1400 LST on 8 August 1966. Eight of the 10 soundings were considered optimum. The first firing on 6 August 1966, 1200 LST, failed to attain altitude and the ninth firing on 8 August 1966, 1200 LST, yielded no data because of a radar failure. The 1400 LST soundings on the 7th and 8th of August 1966 utilized the heavier copper chaff, thus the lower maximum altitudes and longer profiles.

A modified M-33 radar was used for tracking. All tracking was manual, rather than automatic to minimize searching over the chaff clouds. One hundred thousand yards was the range limitation of the M-33 tracking facility, and tracking most of the light glass chaff rounds was terminated due to excessive range. Use of the very light weight .001 glass chaff is necessary to achieve wind sensitivity at the low densities encountered in the 80-90 km region; however, dispersion of this chaff becomes a problem at lower altitudes, and a lower limit of usefulness is approximately 65 km. Wind data were reduced graphically from radar plots, utilizing standard MRN reduction techniques.

3. Discussion Of Wind Data

The maximum easterly component measured (before additional smoothing was applied) was 108 mps for the 1400 LST sounding on 7 August 1966 at 82 km which was the top of the profile (Figure 2). These maximum easterly components in excess of 100 mps are in favorable agreement with grenade data obtained over Point Barrow, Alaska, during August 1965, by Theon, et al. (1966), which showed

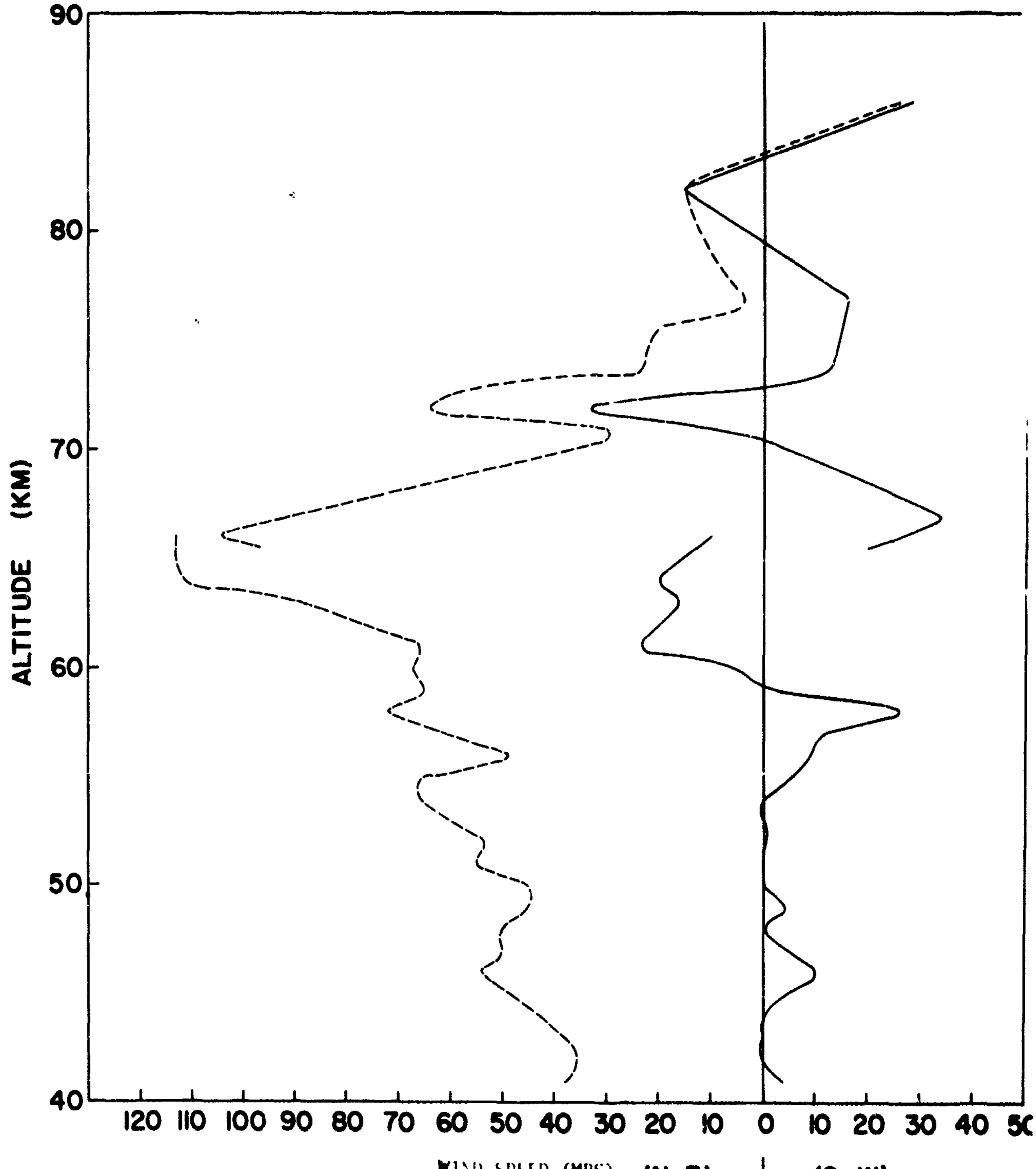

Figure 1 - Component wind profile obtained at White Sands Missile Range, New Mexico, for 8 July 1966. Zonal components are dashed curves and meridional components are solid curves

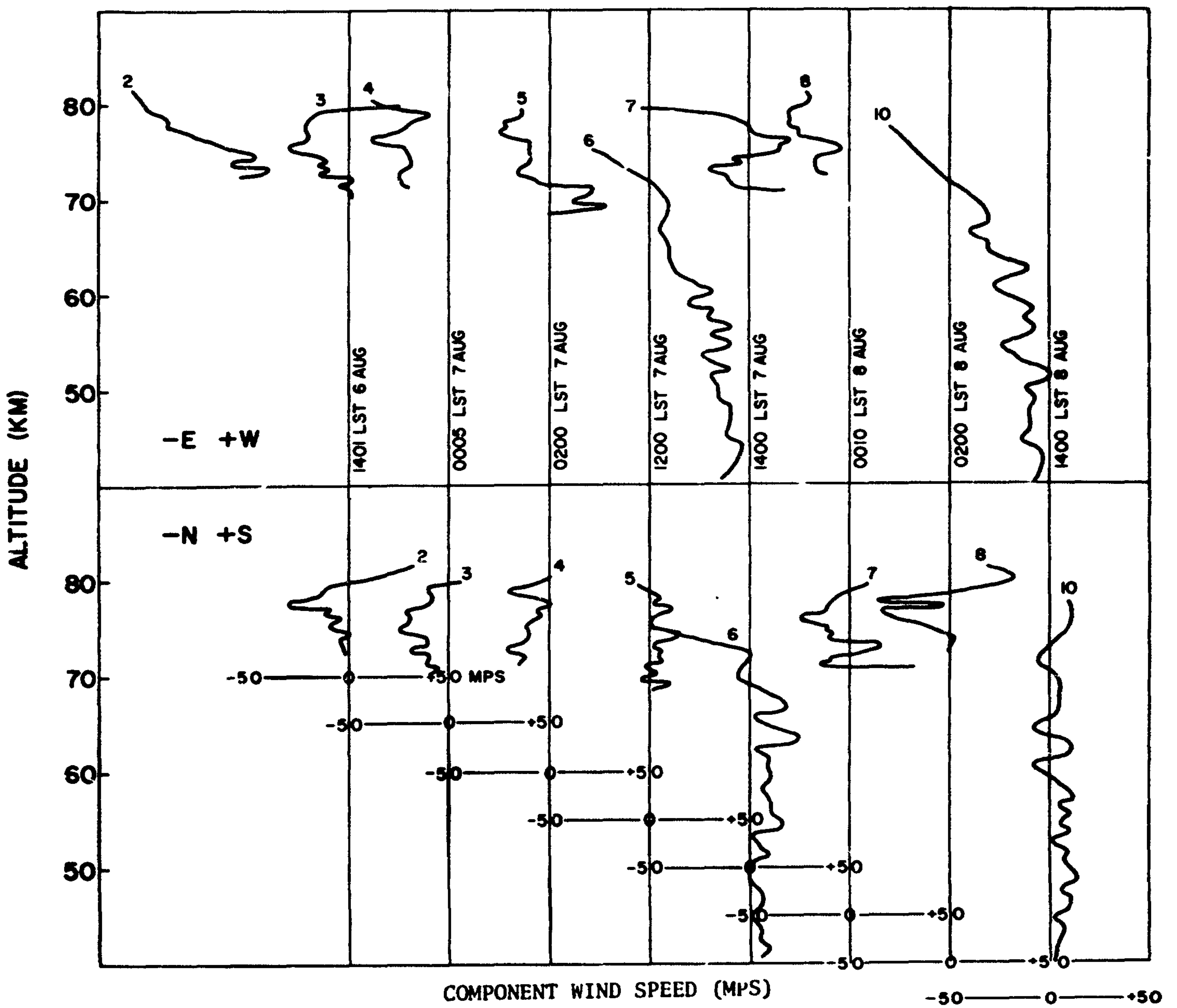

Figure 2 - Component wind profiles obtained at Fort Greely, Alaska, in August 1966. Zonal components are plotted above, meridional components below. Components from the south and west are positive; north and east are negative. Number near the top of each profile refers to the firing number in the 10-rocket series.

easterly components of approximately 105-110 m/sec. near 83 km. Of the six high-altitude glass chaff rounds fired at Fort Greely, the heights of maximum easterly components ranged from 76 to 82 km Two of these maxima were at the top of the soundings; therefore, the maximum upper level of these easterlies is still not well defined. These data to 82 km, coupled with the 5-year data summaries of the MRN publications from Fort Greely, Point Mugu and WSMR (IRIG 1964, 1965), show the level of maximum summer easterly flow to be located at a higher altitude in the polar region than at lower latitudes. In addition, these high zonal velocities are somewhat surprising when compared with the light (< 30 mps) easterly flow predicted for this region by Murgatroyd (1957), Batten (1961), Kochanski (1963), and Kantor and Cole (1964). In his meridional cross section for the summer hemisphere, Batten shows the core of easterlies to be centered near 25° latitude at 55 km altitude with speeds of 50-60 mps. This core of easterlies is shown to slope upward and diminish toward the pole with maximum easterlies of 35 mps near 70 km. In the more recent work by Kantor and Cole, a mean meridional cross section for July shows the core of easterlies to be centered near 30° N latitude at 60 km altitude with speeds of 50-60 mps. No slope is shown in the level of maximum easterlies, but a decrease in speed toward the pole with maximum easterlies of 30-40 mps at 60°-75° N latitude is noted. These summer 1966 measurements from 32° and 64° N latitude indicate that this picture should be modified, the core somewhat higher in both speed and altitude at 25°-35° latitude and a steeper slope toward the pole with a speed of 100 mps near 80 km and 65° N.

A study by Fogle (1966a), shows that noctilucent clouds are observed near the mesopause between 45° N and 80° N latitude (best at about 60° N) from March through October (more frequently during June through August). The firing schedule in the first week of August 1966 at Fort Greely (64° N) was planned with this maximum observance of noctilucent clouds in mind.

One explanation for the formation and maintenance of these extremely high-altitude clouds is offered by Webb (1965, 1966a, 1966b, 1966c) in his treatment of the stratospheric tidal jet (STJ). Webb contends that continuous irradiation of the polar stratopause region in midsummer results in elongation of the diurnal heat ridge, thus causing the tidal component of the stratospheric circulation to circle the pole in the nighttime sky, and resulting in enhancement of the circulation at these high latitudes (Figure 3). Convergence of this tidal circulation and the resultant vertical motion in the sunrise to midnight sector are postulated to contribute the necessary vertical velocities required for the suspension of particulate matter in the observed noctilucent clouds. Under this postulate, winds observed at high latitude summer should show a greater zonal flow in the upper mesosphere than in the stratopause region where the

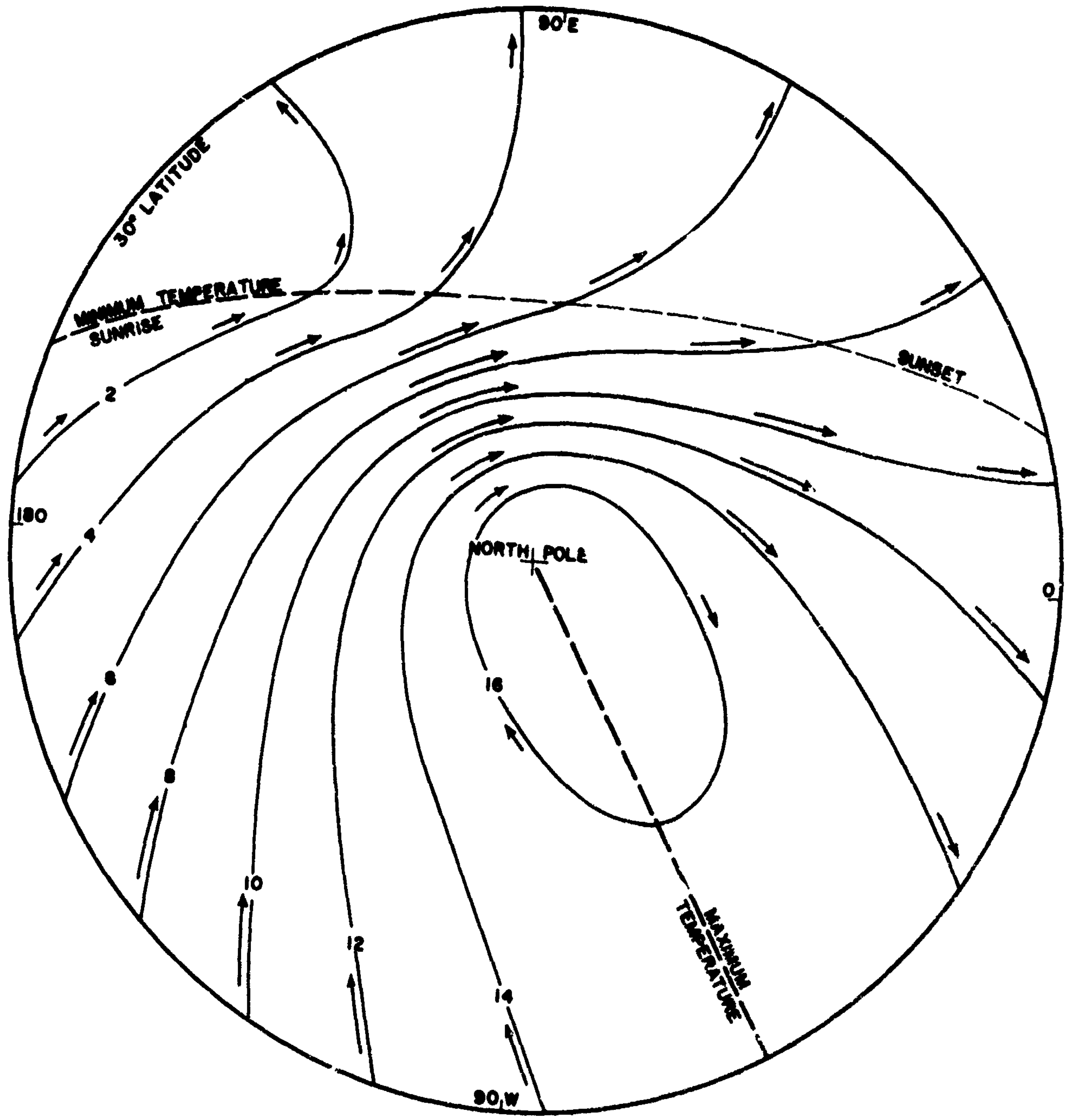

Figure 3 - Diurnal perturbation of the stratospheric circulation at summer solstice time projected on the equatorial plane. Temperature contours are thin solid lines and the wind field is indicated by arrows. (Webb, 1966b)

heat input occurs at middle and low latitudes. In addition, the zonal flow near 0200 LST should be stronger than that at 1400 LST provided, as Webb states, that loss mechanisms do not cause modifications.

Figure 4 shows in components the averages of the night soundings versus the day soundings. (To smooth out random tracking errors, wind profiles were averaged over 2-km intervals before overall averages were made.) The day average zonal component is 23 mps faster at 80 km than the night zonal component and remains faster down to 76 km where the night average is stronger. Because the night average represented more soundings than the day average, comparisons of 0000 LST versus 1200 LST soundings (Figure 5) and 0200 LST versus 1400 LST soundings (Figure 6) were made. Comparison of the 0200 LST versus 1400 LST soundings is similar to the day versus night comparison with the 1400 LST average greater above 77 km and 0200 LST average greater below. The comparison of two midnight soundings with the one noon sounding shows a somewhat different picture. The zonal component from the noon sounding is stronger with exception of the 79 km level at the top of the profile.

A maximum in zonal component between midnight and 0200 LST due to the STJ was not present on the nights of our observations at the highest levels. Whether this is due to the action of certain loss mechanisms, masking by other components of the general circulation, or to our time and location of observations is not clear at this time. Additional observations at higher latitudes near sunrise will be required to clarify this structural feature.

Lindzen (1966) computed theoretical values for the thermally driven atmospheric tides. For 60° N between 70 and 80 km, the meridional component of the diurnal tide was computed to be maximum northerly near local midnight with an amplitude of 8-9 mps. The zonal component was computed to be maximum westerly near 1800 LST with an amplitude of 7-8 mps. Although the data sample from Fort Greely is small, Figures 5 and 6 show general agreement with this picture in the phase of the meridional component and somewhat in amplitude. Since no soundings were made near 1800 LST or 0600 LST (the times of maximum and minimum westerly tidal components, respectively) the zonal component is difficult to compare. However, the relatively small difference in the 1200 LST and 0000 LST zonal components appears to be in general agreement in phase and amplitude while the phase at 1400 LST versus 0200 LST is not. The meridional components indicate a resultant flow from the north. This agrees with the concept of a general circulation from the summer pole to the winter pole (Kochanski, 1963).

Noctilucent clouds were not observed at Fort Greely on these nights, possibly due to tropospheric smoke haze in the vicinity, but

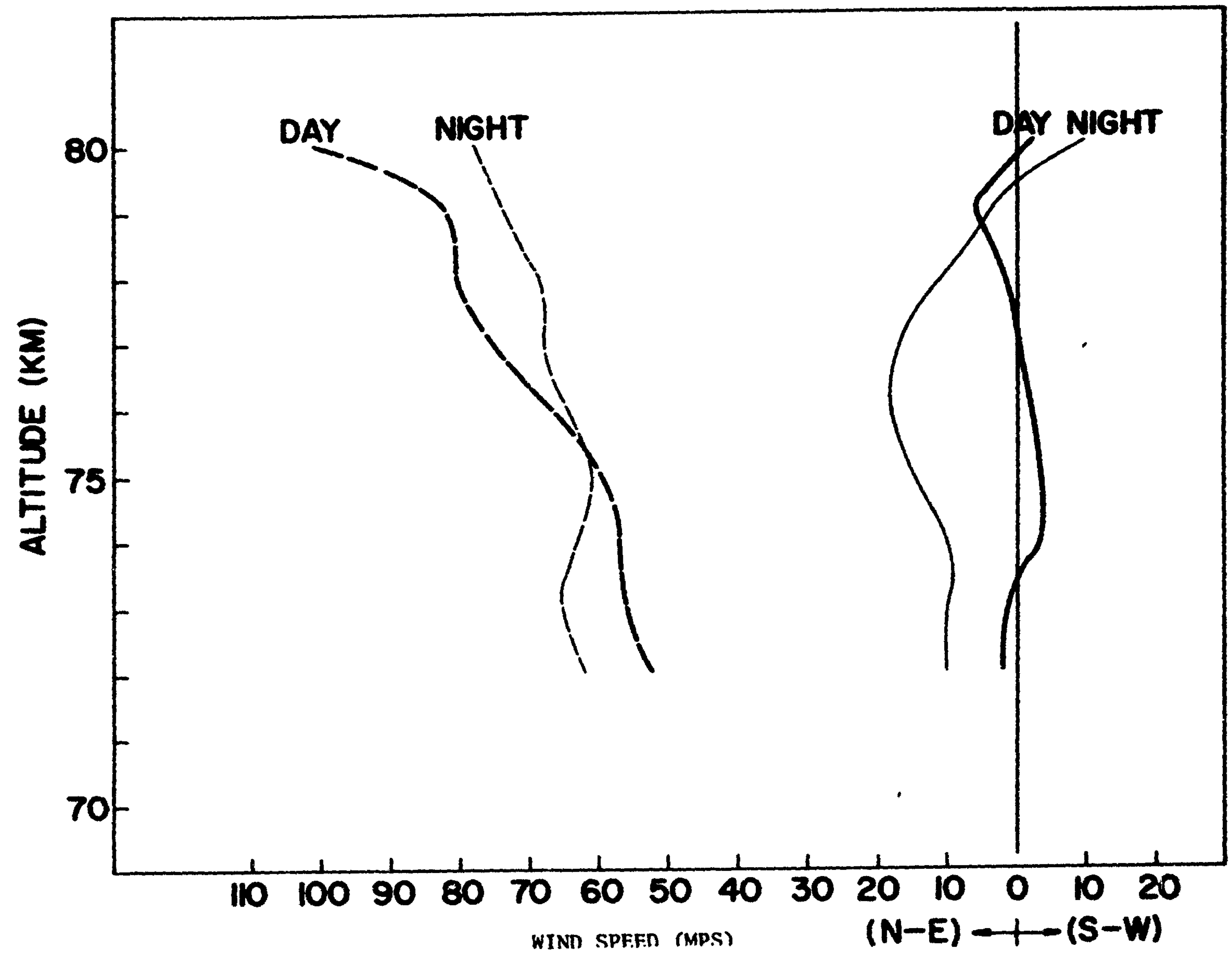

Figure 4 - Day-night average component wind profiles obtained at Fort Greely, Alaska, 6, 7, 8 August 1966. Zonal components are dashed curves and meridional components are solid curves.

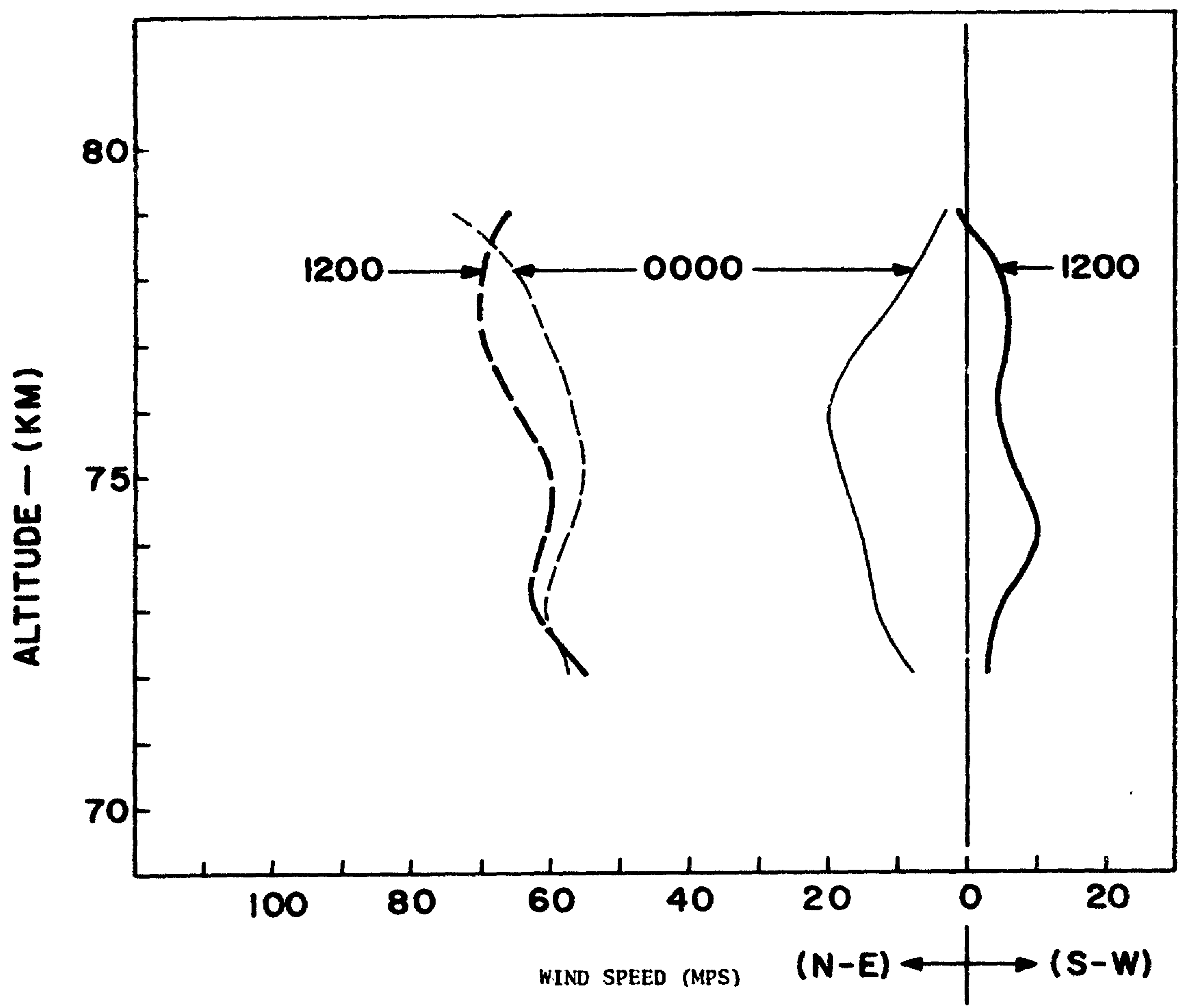

Figure 5 - Noon-midnight (local times) average component wind profiles obtained at Fort Greely, Alaska, 6, 7, 8, August 1966. Zonal components are dashed curves and meridional components are solid curves.

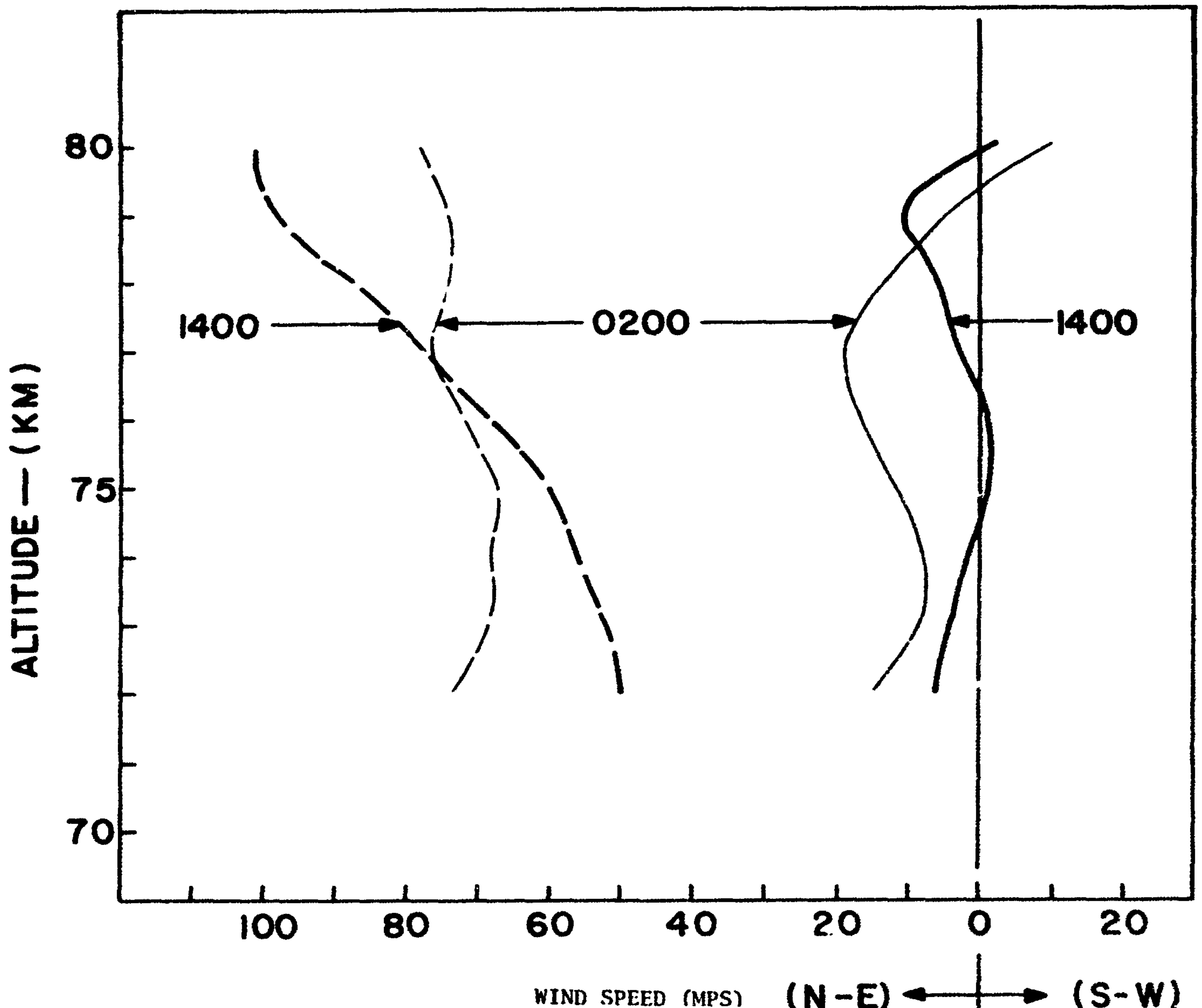

Figure 6 - 1400-0200 (local times) average component wind profiles obtained at Fort Greely, Alaska, 6, 7, 8 August 1966. Zonal components are dashed curves and meridional components are solid curves.

sightings were reported over northern Canada (Fogle, 1966b) (Figure 7). It is hoped that future field measurements can be made when noctilucent clouds are present directly over the observation point and that winds can be measured well above the 82-km level of maximum occurrence of noctilucent clouds. Comparison of any such data with the data just presented is expected to give valuable information of detailed circulation patterns involved in the formation and maintenance of noctilucent clouds.

4. Fall Rate Analysis

The vertical wind velocities which are assumed to be responsible for the suspension of noctilucent cloud particles should also affect the fall rate of the very light .001 glass chaff. Since noctilucent clouds were not observed over Fort Greely, the necessary vertical wind velocities may have been absent on these nights. Nevertheless, the fall rates were computed, and the comparisons show some very interesting results. Figure 8 shows the average fall rate from the six glass chaff observations at Fort Greely and the averages of the two midnight and two 0200 LST observations. With the exception of the top point, the 0200 LST fall rates are slower than those at midnight which is in agreement with the STJ hypothesis of minimum fall rate after midnight. From these results, it appears that noctilucent cloud particles would have a slower fall rate near 0200 LST.

Of particular interest, all six of these glass chaff fall rate profiles show a sharp decrease in fall rate near 77 km, followed by additional fluctuations below. Upon averaging the six profiles we see that all oscillations average out with the exception of the one at 77 km (Figure 8). Examination of the WSMR glass chaff fall rate profile of 8 July (Figure 9) shows similar behavior near 77 km. Two additional high-energy Lokis were fired on 20 and 23 September 1966, at WSMR to study this feature further. The profiles at 1206 LST on 20 September 1966 and at 1745 LST on 23 September 1966 (Figure 9) showed the fluctuations near 77 km, although the latter was perhaps less clear. The 1745 LST firing time was the only one that was near neither midnight nor midday, thus the lack of a sharp fluctuation near 77 km might possibly be attributed to this time factor. The sudden decrease in fall velocity near 77 km could be caused by vertical motions, an area of steep density lapse rate, or this could be the level at which the chaff becomes dispersed to such a degree that the radar may begin to search over the chaff cloud. The latter reason seems less likely since the average fall rate still showed the decrease.

Temperature and density data in the 70-80 km region are sparse; however, data by Rofe (1966), Thiele (1964), Peterson, et al. (1965) show lapse rate fluctuations in temperature and density in this altitude range. These data are from falling spheres, and there is some

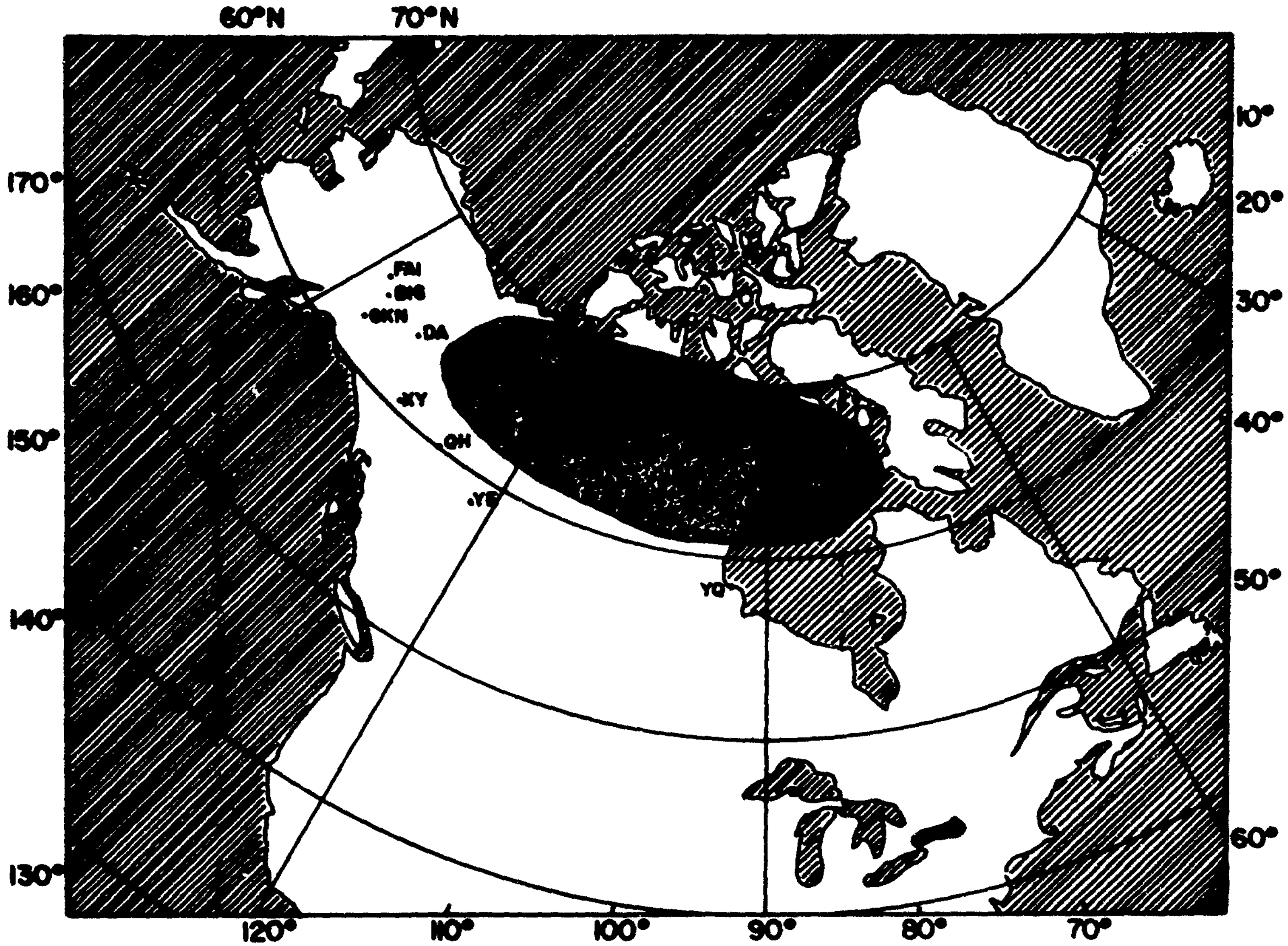

Figure 7 - Approximate area of noctilucent cloud display observed on nights of 6 and 7 August 1966 over northern Canada. (Fogle, 1966b)

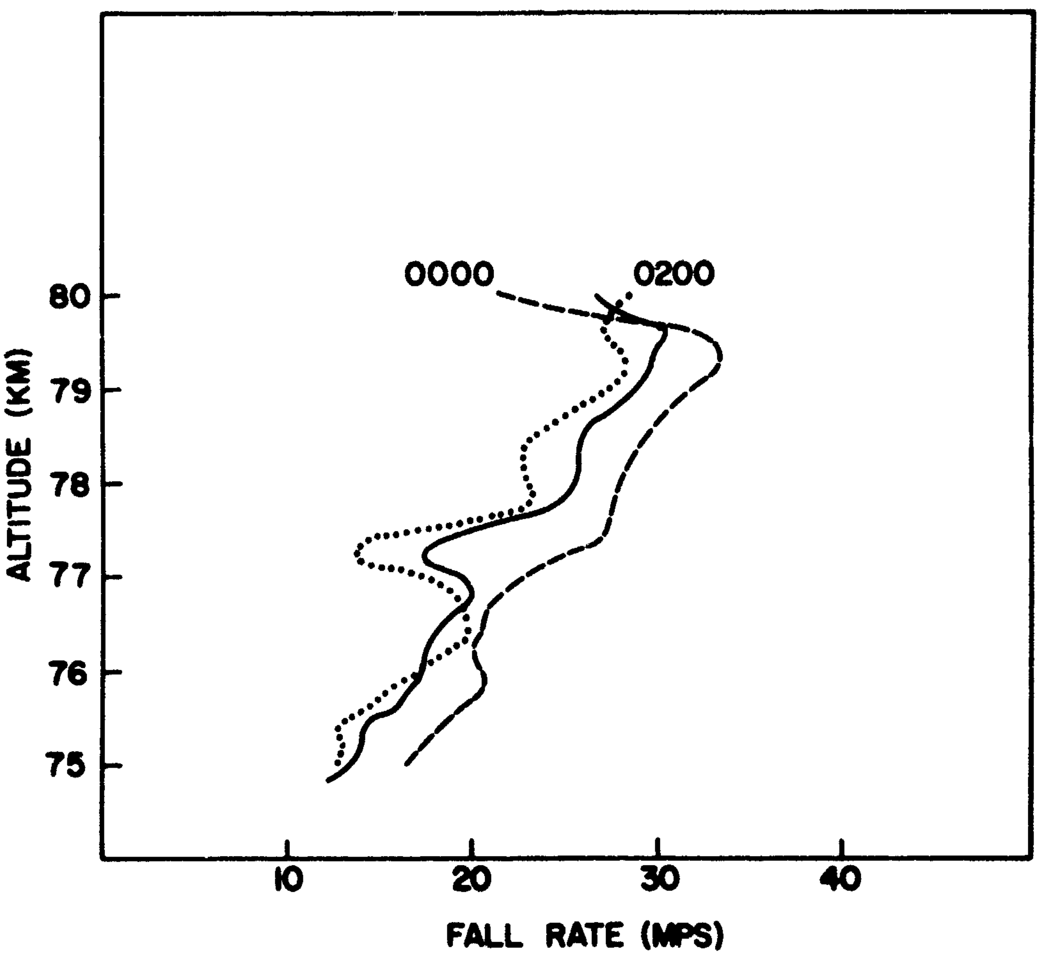

Figure 8 - Average fall rates of 0.001 in. diameter glass chaff obtained over Fort Greely, Alaska. Solid curve is average for all six profiles regardless of time. Dashed curve is average of the two fall rates obtained at 0000 LST, and the dotted curve is the average of the two fall rates obtained at 0200 LST.

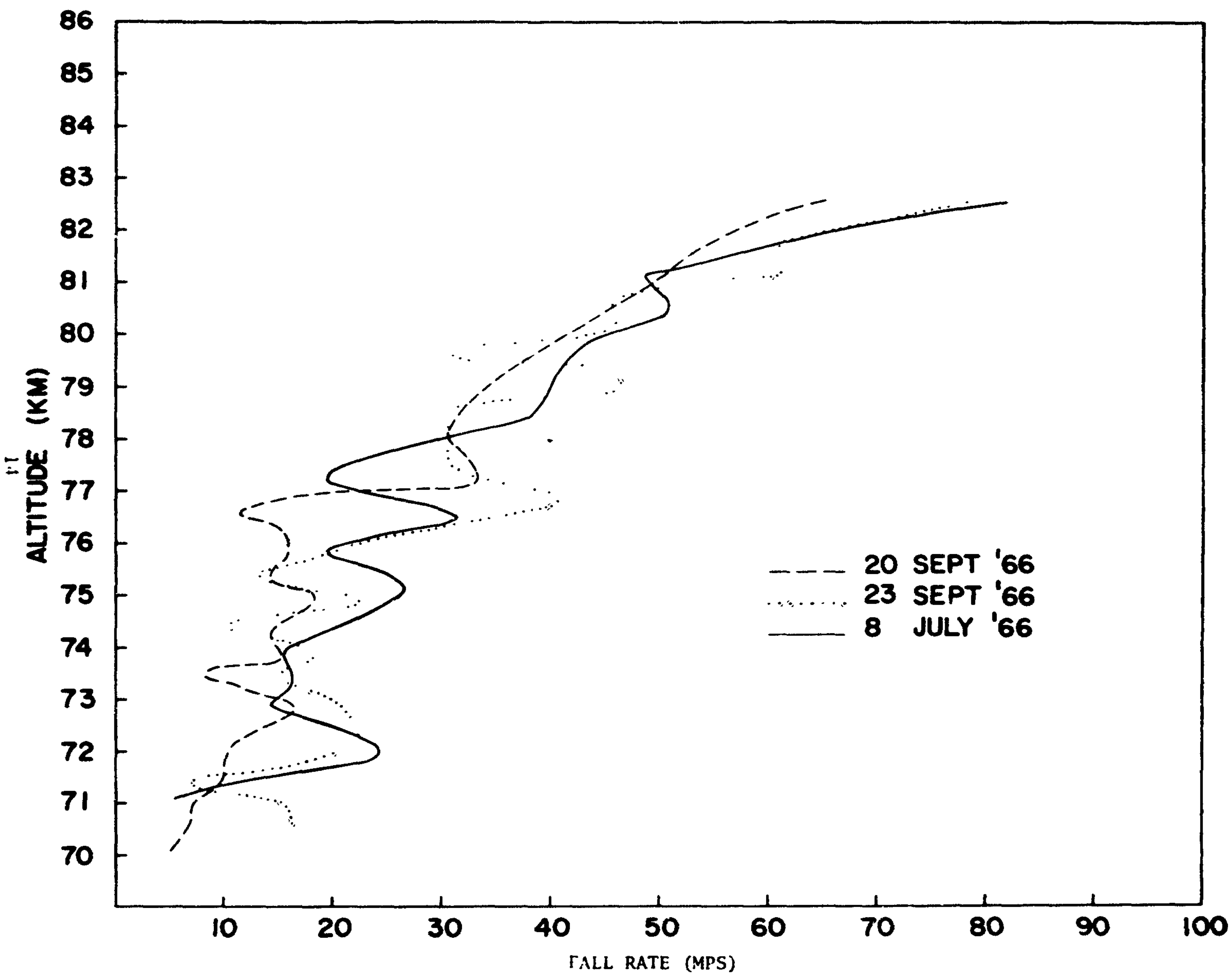

Figure 9 - Fall rate profiles for 0.001 diameter glass chaff obtained over White Sands Missile Range, New Mexico, on 8 July 1966, 20 September 1966, and 23 September 1966.

doubt whether these fluctuations are real due to the passage of the inflatable type sphere through the transonic region in this area and the subsequent 50% decrease in drag coefficient. The slow (20-30 mps) fall rate of the glass chaff indicates that fluctuations in density and temperature lapse rates in the 70-80 km region may be real characteristics of the upper mesosphere.

5. Conclusions

Wind measurements to 82 km at 64° N latitude in early August revealed maximum easterly winds in excess of 100 mps near the mesopause. These observations require a revision of the mean summer meridional cross sections wherein the strong subpolar easterlies near the mesopause will be shown. The wind data presented are in general agreement with current tidal theory. The high velocity of the subpolar circulation and the lower than average fall rate of the wind sensor of approximately 5 mps at 0200 LST are in accord with the stratospheric tidal jet hypothesis. The sudden decrease in fall rate near 77 km draws attention to this region as one of particular interest. As is true in much of the research in the stratosphere and mesosphere, additional data are required to establish the details of this summer subpolar circulation.

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Mesospheric wind data obtained with a new high altitude Loki system during the summer of 1966 over Fort Greely, Alaska, are presented. Soundings, utilizing very light chaff as a wind sensor, were scheduled near noon and midnight for a 50-hour period. These data are from a sparsely sampled region of the atmosphere. The diurnal variations and the high velocities observed give valuable information regarding noctilucent clouds, atmospheric tidal oscillations, and the mean summer flow near the subpolar mesopause.

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